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Targeting sediment management strategies using sediment quantification and fingerprinting methods

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Cost-effective sediment management is required to reduce excessive delivery of fine sediment due to intensive land uses such as agriculture, resulting in the degradation of aquatic ecosystems. Prioritising measures to mitigate dominant sediment sources is, however, challenging, as sediment loss risk is spatially and temporally variable between and within catchments. Fluctuations in sediment supply from potential sources result from variations in land uses resulting in increased erodibility where ground cover is low (e.g., cultivated, poached and compacted soils), and physical catchment characteristics controlling hydrological connectivity and transport pathways (surface and/or sub-surface). Sediment fingerprinting is an evidence-based management tool to identify sources of in-stream sediments at the catchment scale. Potential sediment sources are related to a river sediment sample, comprising a mixture of source sediments, using natural physico-chemical characteristics (or 'tracers'), and contributions are statistically un-mixed.

Suspended sediment data were collected over two years at the outlet of three intensive agricultural catchments (approximately 10 km^2) in Ireland. Dominant catchment characteristics were grassland on poorly-drained soils, arable on well-drained soils and arable on moderately-drained soils. High-resolution (10-min) calibrated turbidity-based suspended sediment and discharge data were combined to quantify yield. In-stream sediment samples (for fingerprinting analysis) were collected at six to twelve week intervals, using time-integrated sediment samplers. Potential sources, including stream channel banks, ditches, arable and grassland field topsoils, damaged road verges and tracks were sampled, oven-dried ($<40^oC$) and sieved (125 microns). Soil and sediment samples were analysed for mineral magnetics, geochemistry and radionuclide tracers, particle size distribution and soil organic carbon. Tracer data were corrected to account for particle size and organic matter selectivity processes. Contributions from potential sources type groups (channel – ditches and stream banks, roads – road verges and tracks, fields – grassland and arable topsoils) were statistically un-mixed using FR2000, an uncertainty-inclusive algorithm, and combined with sediment yield data.

Results showed sediment contributions from channel, field and road groups were 70%, 25% and 5% in the poorly-drained catchment, 59%, 22% and 19% in the well-drained catchment, and 17%, 74% and 9% in the moderately-drained catchment. Higher channel contributions in the poorly-drained catchment were attributed to bank erosion accelerated by the rapid diversion of surface runoff into channels, facilitated by surface and sub-surface artificial drainage networks, and bank seepage from lateral pressure gradients due to confined groundwater. Despite the greatest proportion of arable soils in the well-drained catchment, this source was frequently hydrologically disconnected as well-drained soils largely infiltrated rainfall and prevented surface soil erosion. Periods of high and intense rainfall were associated with greater proportions of field losses in the well-drained catchment likely due to infiltration exceeding the saturated hydraulic conductivity of soils and establishment of surface hydrological connectivity. Losses from field topsoils dominated in the moderately-drained catchment as antecedent soil wetness maintained surface flow pathways and coincided with low groundcover on arable soils. For cost-effective management of sediment pressures to aquatic ecosystems, catchment specific variations in sediment sources must be considered.